PAN-PACIFIC ENTOMOLOGIST
70(2): 103–112, (1994)

BIONOMICS AND LIFE HISTORY OF THE GALL MIDGE *CHAMAEDIPLOSIS NOOTKATENSIS* GAGNÉ & DUNCAN (DIPTERA: CECIDOMYIIDAE) ON YELLOW CYPRESS IN BRITISH COLUMBIA

ROBERT W. DUNCAN
Pacific Forestry Centre, Forestry Canada,
Victoria, British Columbia V8Z 1M5 Canada

Abstract.—The bionomics and life history of the gall midge, *Chamaediplosis nootkatensis* Gagné & Duncan, on yellow cypress are described including a detailed account of gall formation, seasonal development, parasitoids, host damage and geographic distribution. This gall midge has caused significant seed production losses and defoliation of yellow cypress at a seed orchard on Vancouver Island. The gall midge is univoltine but has two distinct life cycles determined by microclimatic differences within the tree.

Key Words.—Insecta, *Chamaediplosis, Chamaecyparis,* gall, life history, parasitoids, damage

This paper reports the results of a five-year field study on the biology and impact of *Chamaediplosis nootkatensis* Gagné & Duncan on yellow cypress in a seed orchard on south Vancouver Island.

In recent years, reforestation with yellow cypress has increased due to its high economic value, more frequent harvesting at high elevations (the natural habitat of yellow cypress), and extended planting beyond its natural range (Grossnickle & Russell 1989). Increased demand for yellow cypress seed, combined with difficulties in securing wild collections, has made protection of the seed orchard crop vital. Observed damage indicates that this recently described gall midge (Gagné & Duncan 1990) has the potential to become a significant economic pest of yellow cypress grown either in seed orchards or as ornamentals.

MATERIALS AND METHODS

Geographic distribution within British Columbia was ascertained from field collections made throughout the host range during 1987–89. Host susceptibility of other *Chamaecyparis* spp. or intergeneric hybrids was determined by: (1) planting trees of each species within 2 m of heavily infested trees, monitoring gall formation over a two-year period and (2) confining freshly emerged adults in cages containing potted trees. Species included in trials were *Chamaecyparis obtusa* (Seibold & Zuccarini) Endlicher, *C. pisifera* (Seibold & Zuccarini) Endlicher, and *Cupressocyparis leylandi* (Dallimore & Jackson) Dallimore.

Detailed field studies were conducted at a forest industry seed orchard near Saanichton, British Columbia. Yellow cypress at the study site were 3–18 years old and varied in height from 1–7 m.

To determine the influence of shade and exposure on rates of larval development within a tree, four 15-cm branch tips were collected at weekly intervals from February, 1987, to July, 1990, at both exposed and shaded microsites of each tree sampled. All galls on each branch sample were dissected and developmental stages determined by measuring head capsule widths at 200× magnification using a micrometer.

Table 1. Body measurements (mm) of *C. nootkatensis*.

Stage	Head capsule width (n = 50)		Body length (n = 200)		Body width (n = 200)	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Instar I	0.023	0.023–0.027	0.42	0.32–0.43	0.18	0.14–0.22
Instar II	0.043	0.041–0.050	1.37	0.80–1.62	0.49	0.30–0.61
Instar III	0.092	0.090–0.099	1.86	1.20–3.24	0.68	0.36–0.83
Pupa male	—	—	2.42	1.80–2.88	0.66	0.65–0.72
Pupa female	—	—	2.71	2.05–3.24	0.77	0.76–0.79

Oviposition sites and density of egg deposition were determined by mapping egg distribution on 20 15-cm branch tips. Oviposition behavior was observed in the field. Mating behavior, adult longevity and egg hatch were determined from observations of laboratory-reared specimens. Potential fecundity was determined by dissecting and counting eggs in newly emerged females.

Adult midge and parasitoid emergence was monitored in two ways: (1) by counting adults caught on four 100 mm × 50 mm yellow sticky traps set out at weekly intervals from mid March to mid August in 1988 and 1989, and (2) by examining marked galls weekly at exposed and shaded microsites. The round exit holes of the parasitoids were easily distinguishable from the slits produced by midge pupae as they pushed through the wall of the gall. Information on parasitism was obtained by rearing adult parasitoids from galls and by dissections of weekly gall collections.

Data relating to the incidence, location, form, growth and development of galls were derived from detailed counts, measurements and descriptions of galls on 15-cm branch tips collected throughout the year. Specific collections of male and female strobili were made to assess the level of damage to reproductive structures. Development of individual galls (increase in size, color change, senescence and shedding of galls) was tracked by examining 100 marked galls weekly over a five-month period.

Chamaediplosis nootkatensis Gagné & Duncan

Egg.—Eggs orange, elongate oval (Fig. 2a), average 0.270 mm long and 0.106 mm wide.

Larval Instars.—Distribution of head capsule width measurements revealed 3 distinct size classes, as 3 instars (Table 1). First-instars bright orange, with distinct internal red spot (Fig. 2b). Second-instars somewhat larger, bright orange, lacking a distinct internal red spot (Fig. 2b). Head capsule width increases about twofold between each instar. Final (third) instar larvae (Fig. 2b) easily distinguished by a sternal spatula near anterior end. Immediately prior to pupation third-instar changes to somewhat duller orange, and anterior fades to a creamy color.

Pupa.—Pupation within galls. Male pupae smaller (Table 1), duller in color than the females, which have bright orange abdomen (Fig. 2d).

Adult.—Females are slightly larger, heavier bodied, more brightly colored than males (Fig. 2c). The ratio of males to females 0.9:1.0 (n = 1000).

Distribution and Hosts

Chamaediplosis nootkatensis has been collected throughout most of the range of yellow cypress in British Columbia (Fig. 1), except for the Queen Charlotte Islands and the Selkirk Mountains, which are isolated from the main host dis-

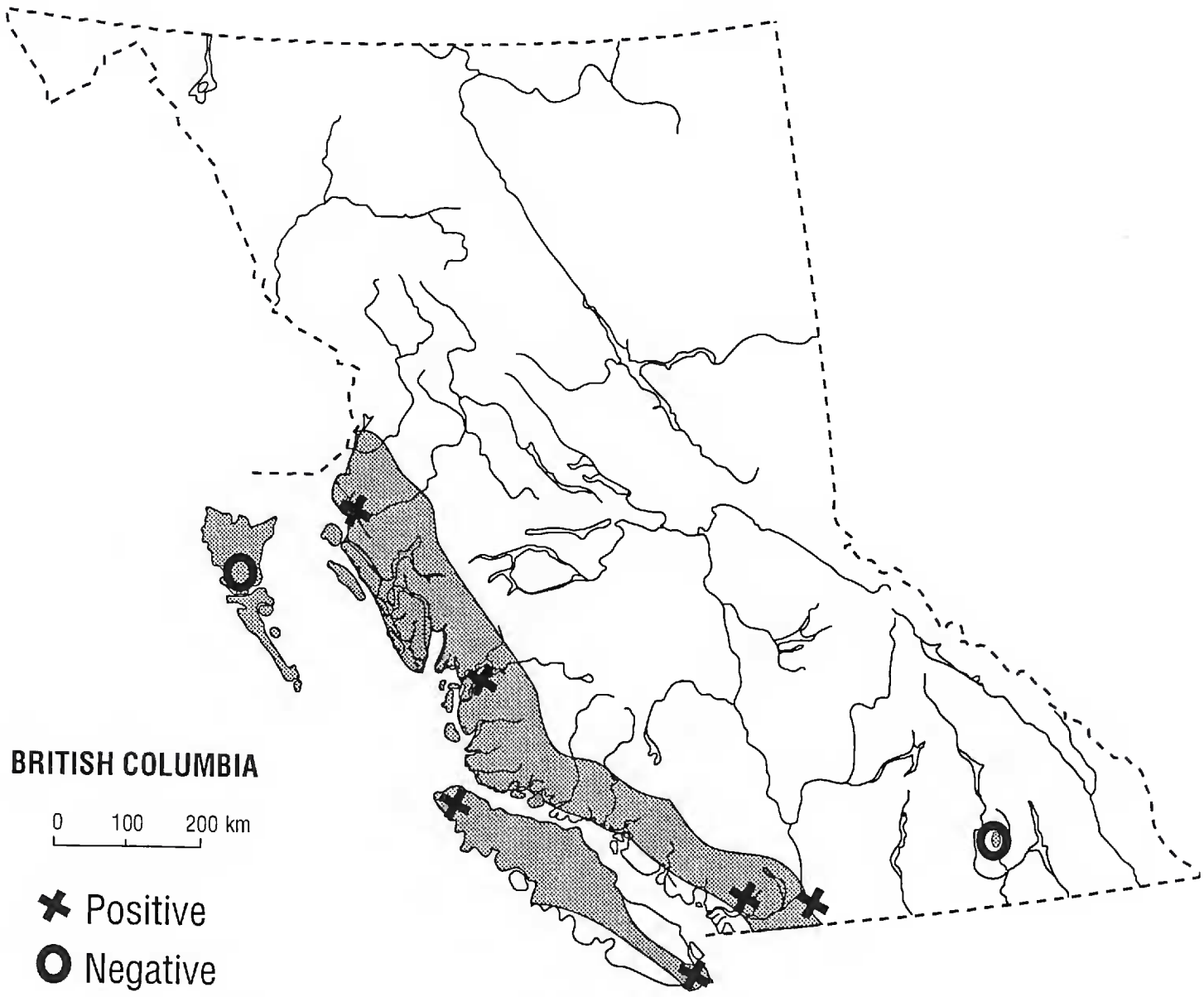

Figure 1. Distribution records for *Chamaediplosis nootkatensis* in British Columbia. Shaded area represents distribution of the host *Chamaecyparis nootkatensis*.

tribution (Hosie 1979). Collections have been made from sea level to near tree line. It is likely the midge is also present in adjacent areas of both Alaska and Washington, since it has been collected at sites in both extreme northern and southern coastal British Columbia.

Chamaediplosis nootkatensis has not yet been recorded attacking other *Chamaecyparis* spp., or intergeneric hybrids despite extensive surveys of ornamental trees growing near the seed orchard site. Successful attacks were not observed in any of the host specificity trials.

Gall Development

Galls in the earliest stage of development can be recognized by a slight swelling of the tip and a kink in the terminal scales (Fig. 2e). A distinct feeding chamber is not formed within the gall until just before the larva reaches the second instar.

Small, readily recognizable galls (Fig. 2f) are apparent by the time early second-instars are present. Galls are globose and similar in color to the foliage. Typically, the basal portion of two to four pairs and occasionally up to six pairs of scale leaves are modified as a result of gall development. The distal part of each scale remains relatively unchanged and protrudes from the gall. The galls grow (Table 2) as the larvae mature and reach an average maximum diameter of 2.6 mm when

Figure 2. Life stages, galls, parasitoids and damage of *Chamaediplosis nootkatensis* on *Chamaecyparis nootkatensis*: (a) Eggs in crevices of overlapping scale leaves. (b) Comparative sizes of first, second and third instars, scale in mm. (c) Male (upper) and female (lower) adult midge. (d) Female (upper) and male (lower) pupa, scale in mm. (e) Early gall. (f) Galls containing early second instar (left) and third instar (right). (g) Newly emerged female midge and pupal exuviae. (h) Dieback on heavily galled branch. (i) Subapical and apical galls. (j) Galled (left) and normal (right) male strobili. (k) Galled (right) and normal (left) female strobili. (l) Eclosion of *C. nootkatensis*. (m) First instar mined into tip. (n) Larva of *Platygaster* sp. in second instar host. (o) Pupa of *Platygaster* sp. in host gall. (p) Larva of *Mesopolobus* sp. nr. *finlaysoni* on host pupa.

Table 2. Measurements (mm) of *C. nootkatensis* galls.

Terminal structure galled and larval stage	Gall length $n = 200$		Gall width	
	$\bar{x}$	Range	$\bar{x}$	Range
Vegetative with early second instar	2.05	1.33–3.03	2.13	1.14–3.03
Vegetative with late second/third instar	2.58	1.90–3.80	2.62	1.52–3.80
Reproductive (microsporangia) with late second/third instar	3.34	2.89–3.88	2.88	2.28–3.72
Reproductive (megasporangia) with late second/third instar	3.01	2.20–3.88	2.65	1.90–4.10

the larva is in the late second instar or early third instar (Fig. 2f). Although the shape of the gall is still generally globose, it varies considerably. The wall averages 0.61 mm in thickness and the larval chamber averages 1.5 mm in diameter. The color of the gall gradually changes from green to yellowish-green and the thickness of the walls decreases during third instar as the larva completes its feeding. The prepupal larva orients itself head upwards in the gall and wears a circular area 0.7–0.8 mm wide through the spongy tissue lining the gall leaving only a thin layer of epidermal tissue. Presumably this abrasion of gall tissues on the inner wall is a result of the axial rotation of the prepupal larva within the gall. By the time pupation occurs, the galls turn a bronze, yellow or reddish color and the walls of the gall become much thinner as the gall tissues begin to dry up. After emergence of the midge (Fig. 2g), the galls and supporting shoot, down to the nearest crotch, turn brown, dry up and drop off (Fig. 2h). At this stage, heavily galled trees appear noticeably scorched. Although most galls develop at the tip of a shoot, about 10% occur in subterminal positions up to 50 mm below the apex (Fig. 2i).

Both male and female strobili are indiscriminately attacked in the same ratio as vegetative tips (Table 3). Galled male strobili are ovoid and appear similar to unaffected male strobili but are less elongate and somewhat stouter (Fig. 2j). The swollen axis of a galled strobilus is loosely covered with somewhat reduced microsporophylls and undeveloped remnants of microsporangia. The lack of mature pollen sacs causes galled strobili to remain green in late winter; unaffected strobili turn bright yellow as their pollen matures. Galled female strobili are globose when mature and are readily recognized by the presence of six to eight stigmata that persist through gall development and noticeably protrude from the distal end of the gall (Fig. 2k).

Galls are unilocular but may occasionally appear to be plurilocular where two or three galls form in close proximity. They may be stacked linearly along a branch or laterally on a short adjacent shoot. Galls are very spongy; the interior of the gall is composed of large undifferentiated cells which provide nourishment for the developing larva. During the final instar, larval feeding gradually reduces the spongy tissue lining the wall of the chamber.

Life History and Behavior

This species is univoltine. The seasonal life cycle, however, is highly variable and site dependent. Larval development was more advanced in galls located on

Table 3. Relative occurrence of galls on different types of terminal structures.

Terminal structure	1987	Sample size	1988	Sample size	1989	Sample size
Vegetative tip	1.4%	2959	18.5%	4813	11.1%	2440
Microsporangia	4.0%	681	16.6%	1101	12.8%	500
Megasporangia	2.3%	52	22.2%	90	10.6%	603

warmer microsites (open to sun with a south or west aspect) (Fig. 3) than those on cooler microsites (shaded with a north or east aspect) (Fig. 4). Each gall usually had a single larva; however, two occurred occasionally (3%) and three rarely (0.4%) (n = 1000).

Adult emergence began in late March or early April on the warmest sites and continued until early August on the coolest sites. Adult emergence occurred continuously over this period with peak emergences in the first two weeks of April on south-facing exposed branches and in the middle two weeks of both April and June on north-facing or shaded branches. Copulation occurred within hours of emergence and the pairs disengaged after a union lasting only a few seconds. The females laid their eggs singly, close to a crevice formed by overlapping scale leaves (Fig. 2a) either on the upper or lower surface of the branchlets and usually near the tip. Females and males were observed in flight during daylight hours; they are weak fliers and generally remained close to the branches. Once ovipositing females were settled on a branch, they began ovipositing on distal areas of the branches and branchlets and progressed to more proximal areas. They walked to each site and oviposited with the ovipositor oriented distally to the trunk. Over a 45-minute period, a single female was observed to lay 31 eggs, punctuated by

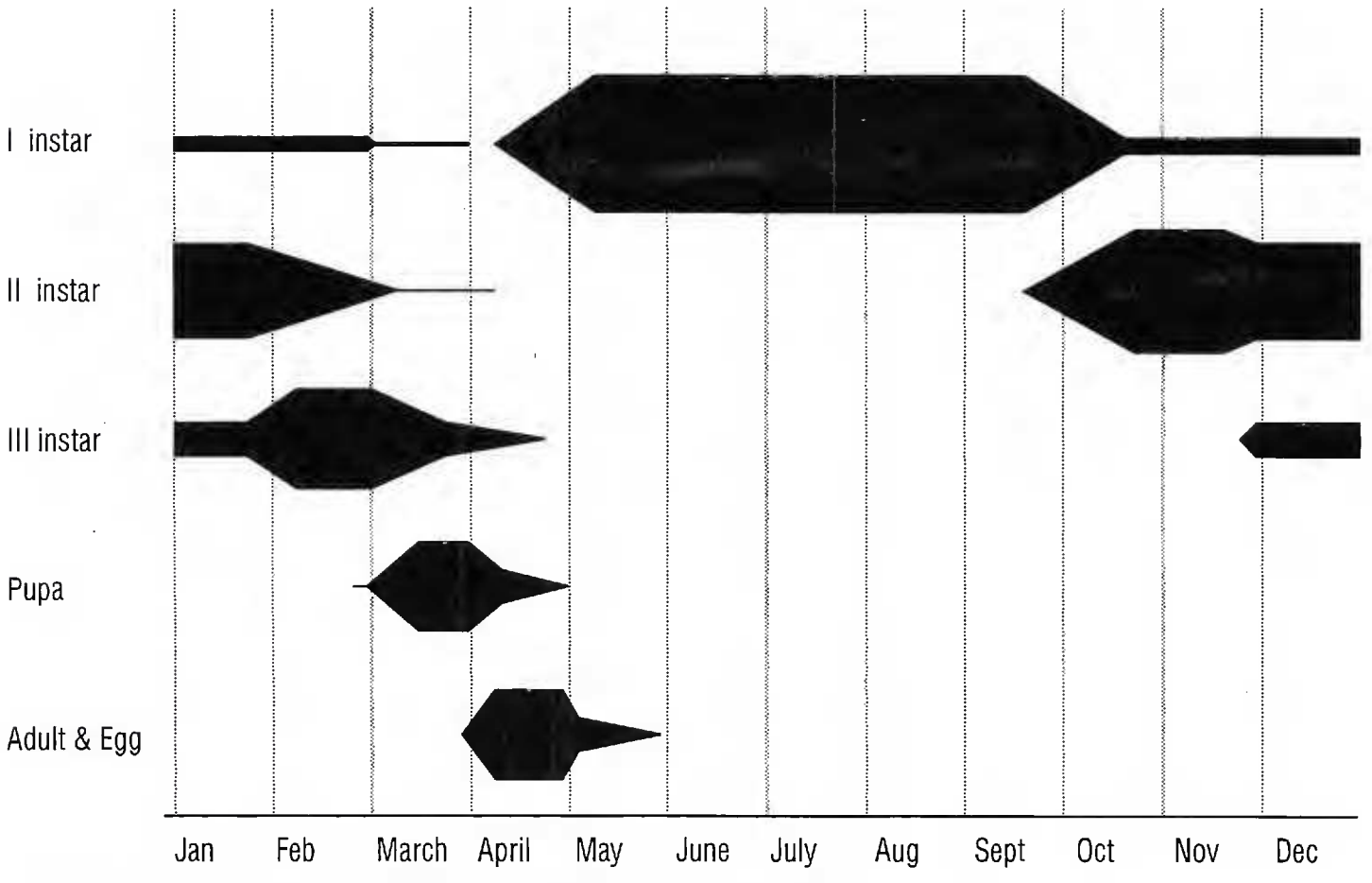

Figure 3. Life cycle of *C. nootkatensis* at warm microsites.

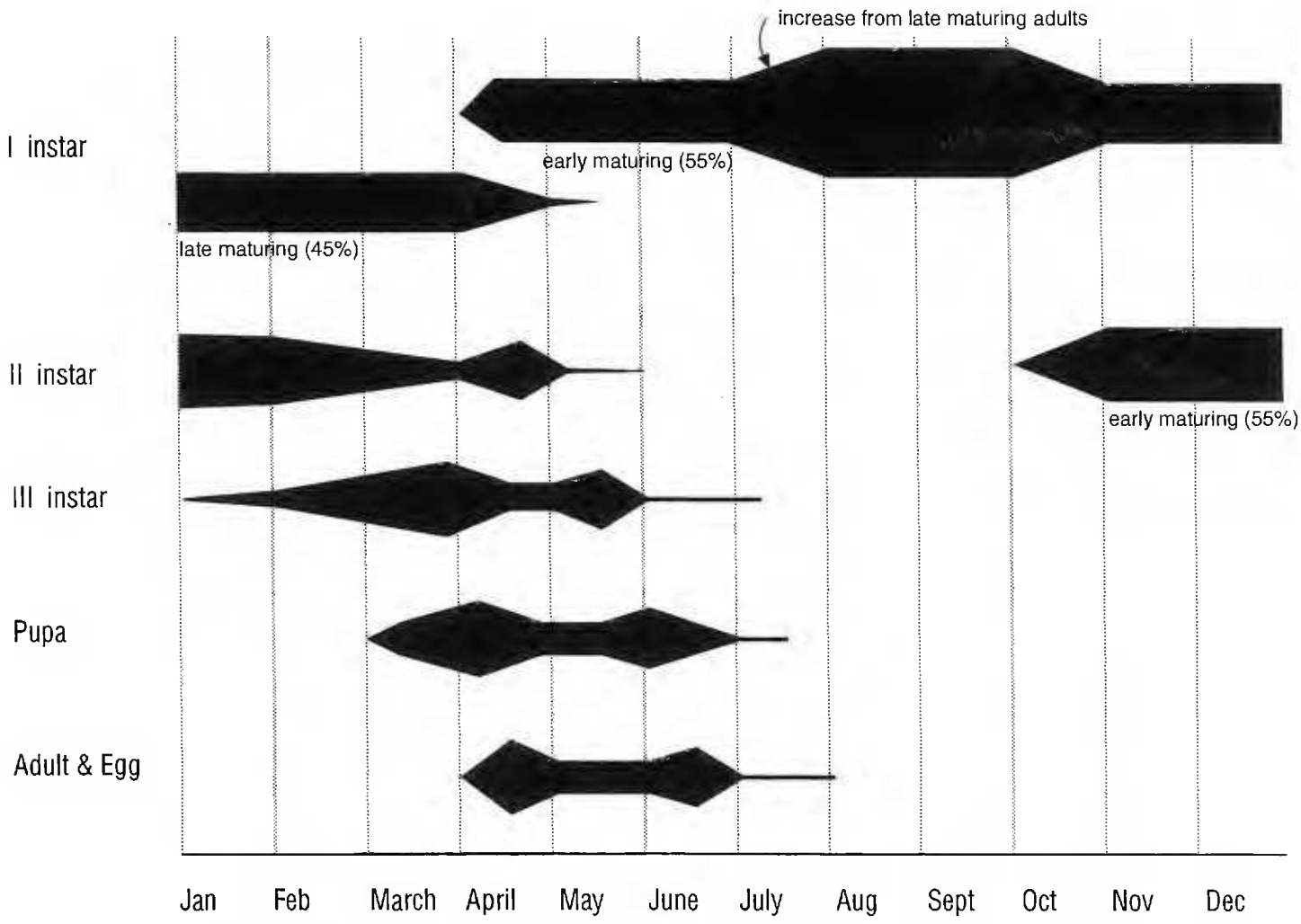

Figure 4. Life cycle of *C. nootkatensis* at cool microsites.

several 3–5 minute rest periods. Adults held in vials lived approximately 7 days at 20° C, 17 days at 10° C and 21 days at 0° C.

Dissections of 20 newly emerged females indicated that the mean fecundity per female was 102.5 eggs (range 75–124). Eggs hatched in four days at 20° C. Newly emerged larvae (Fig. 2l) mine into a nearby scale leaf lodging either at the base of a scale leaf or in the pith, usually near the meristematic dome (Fig. 2m). At warm microsites, first-instars molted to the second instar in October and the infested branch tips began to swell into typical galls. Molting into the third instar peaked in February, and most larvae pupated by mid-March. Adults emerged in late March and April. Newly laid eggs were observed on the foliage throughout April. At cooler microsites, most (55%) of the larvae molted to the second instar in October but a significant portion (45%) overwintered in the first instar. Development of the early-maturing fraction at cooler microsites was very similar to that of larvae at warm microsites, but was slightly delayed. Larvae overwintering in the first instar molted to second and third instar in April and May respectively; pupation occurred in late May and adults emerged in mid-June. Much delayed seasonal development was observed in a few galls (<5%) at cooler microsites with small numbers of adults continuing to emerge through July and early August. Eggs were observed on the foliage from June through August. Just before adult emergence, the pupa forced itself through a small slit in the wall of the gall. Following adult emergence, the pupal exuviae usually remained partially protruding from the gall in the emergence hole (Fig. 2g). Almost all unparasitized galls dropped during June and July. Evidence of early gall development was apparent by mid-

May at sites where early-emerging adults oviposited, and by mid July where late-emerging adults oviposited.

In both types of development, a prolonged diapause lasting five or more months occurred in the first instar. The early-emerging population remained as first-instar larvae from April through October and resumed development in the fall as temperatures began to drop; development then continued throughout the winter months except at times of extreme cold (Fig. 3). The late-emerging population remained as first-instar larvae from summer through the following spring (July–April), and resumed development in April as temperatures increased (Fig. 4).

Parasitism.—The dominant species in the parasitoid guild was *Platygaster* sp. (Platygastridae), an egg-larval, primary endoparasite. One other parasitoid *Mesopolobus* sp. nr. *finlaysoni* Doganlar (Pteromalidae), a facultative secondary ectoparasitoid, was consistently reared from *C. nootkatensis.* Although this parasitoid guild is species poor, the genera represented have been reported to be important control agents in other cecidomyiid studies (Ehler 1987).

Platygaster spp. with cecidomyiid hosts oviposit in embryonized eggs (L. Masner, personal communication). My field observations confirmed that peak emergence of *Platygaster* sp. occurred one to two weeks after host emergence and coincided with the period of maximum abundance of *C. nootkatensis* eggs on host foliage. *Platygaster* sp. completed its development primarily in a late host second-instar or, rarely, an early third-instar. Development of the parasite larva was arrested in the host first-instar. Following an unknown triggering mechanism, it developed rapidly during the host second-instar (Fig. 2n). At maturity, it pupated in a cocoon made within the epidermis of the host (Fig. 2o). Normally a single parasitoid or occasionally two parasitoids (13.0%), completed development in a host. The life cycle reported here differs from that of other *Platygaster* spp. in that development is completed in an earlier host stage (second instar) rather than the prepupal or pupal stages reported for other species (Hill 1923). The diameter of the round emergence holes in the galls averaged 0.23 mm. Parasitism by *Platygaster* sp. ranged from 8.9% to 61.4% over the five year study (Table 4).

The pteromalid *Mesopolobus* sp. nr. *finlaysoni* Doganlar attacked third-instar or, more commonly, pupal hosts (Fig. 2p) and completed its development on the stage initially attacked. Adults emerged about one month after the host emerged. The level of parasitism was relatively low, averaging about 6.6% (Table 4).

The attack strategies of the two species of parasitoids complement each other; this reduces competition and makes optimum use of the host material available. *Platygaster* sp., the dominant parasitoid, heavily parasitizes the gall midge early in its development. As *Platygaster* sp. completes its development, the remaining non-parasitized mature larvae and pupae are attacked by the second parasitoid, *Mesopolobus* sp. nr. *finlaysoni.*

Galls containing *Platygaster* sp. discolored to yellow or bronze slightly earlier than nonparasitized galls but dropped somewhat later. Galls containing pupae parasitized by *Mesopolobus* sp. nr. *finlaysoni* discolored and dropped later than nonparasitized galls.

Predation.—An unknown predator, possibly avian, opened and destroyed up to 40% of the galls on some branches. This damage was most evident from March to June. Relatively firm branches in peripheral parts of the tree sustained heaviest predation.

Table 4. Gall abundance and level of parasitism.

Year	Gall abundance (% of tips)	Parasitism (% of galls)		
		Platygaster sp.	*Mesopolobus* sp. nr. *finlaysoni*	Total
1987	1.9%	8.9%	8.0%	16.9%
1988	16.7%	—	—	no data
1989	10.9%	61.4%	6.2%	67.6%
1990	9.4%	—	—	no data
1991	5.8%	50.5%	5.6%	56.1%

Competition.—Although two larvae occasionally completed development in a gall, intraspecific competition for food and space normally insured that only a single larva would mature in each gall.

Interspecific competition occurred in <1% of the galls when *Argyresthia* sp. (Lepidoptera: Argyresthiidae), *Epinotia hopkinsana* (Kearfott) (Lepidoptera: Tortricidae), or *Eriophyes chamaecypari* Smith (Acari: Eriophyidae) occurred on the same shoot or gall. Defoliator competition usually resulted in midge mortality whereas eriophyiid damage rarely resulted in mortality.

Physical Factors.—Although a severe and unseasonable freeze of −12° C occurred in February 1989 when larvae were actively feeding and undergoing rapid development, the low temperatures appeared to have had little effect on the larvae except where the foliage itself was severely burned by cold, dry winds.

History of the Infestation and Damage

Damage was first observed 17 Feb 1987 at the Canadian Pacific Forest Products seed orchard near Saanichton, B.C. The level of galling at that time was 1.9% of the tips. By 1988, the level of galling had increased to 16.7% at this site and then declined progressively each year thereafter and was 5.8% in 1991 (Table 4). At other sites in natural stands the level of attack has been very low (<0.1%).

Studies by Frankie et al. (1987) suggest that there may be a time lag between colonizing midges on urban trees and their natural enemies due to the relative isolation of these trees from natural stands. Since my study site was located in a seed orchard removed from the natural forest the discovery of orchard gall populations by natural enemies may also have been delayed. A low level of parasitism (16.9%) at the outset of the infestation in 1987 appeared to have allowed an unregulated increase in the gall midge population in 1988, followed by a gradual decline in 1989–91 as parasitism increased.

Samples taken from various levels in the host crown showed little difference in the incidence of galling. Density of attack on vegetative growth was similar to that on reproductive structures, suggesting that the midge does not discriminate between the types of terminal structure it attacks. Where the general level of attack was high the losses of cone crop and foliage were similarly high. Vegetative growth supporting a terminal gall is killed to the nearest crotch and all growth beyond a subterminal gall is also killed. Where heavy foliar losses occurred, the general vigour and health of the tree could be adversely affected and future cone crops could be reduced.

Acknowledgment

I am grateful to Vlad Korelus, Manager (now retired) of Canadian Pacific Forest Product's Saanichton seed orchard, for permission to use the orchard as a study site, and to Deborah McLeod, also of Canadian Pacific Forest Products, for her assistance. I thank Leslie McAuley and Jane Seed—both of Forestry Canada—for assistance in measuring specimens and tabulating data, J. Vallentgoed, N. Humphreys, R. Erickson and A. Stewart of the Forest Insect and Disease Survey unit of Forestry Canada for providing field collections of *Chamaediplosis,* and G. Gibson and L. Masner of the Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa for providing identifications.

Literature Cited

Ehler, L. E. 1987. Ecology of *Rhopalomyia californica* Felt at Jasper Ridge (Diptera: Cecidomyiidae). Pan-Pac. Entom., 63: 237–241.

Frankie, G. W., J. W. Brewer, W. Cranshaw & J. F. Barthell. 1987. Abundance and natural enemies of the spindle gall midge *Pinyonia edulicola* Gagné, in natural and urban stands of pinyon pine in Colorado (Diptera: Cecidomyiidae). J. Kans. Entomol. Soc., 60: 133–144.

Gagné, R. J. 1989. The plant-feeding gall midges of North America. Cornell Univ. Press, Ithaca, New York.

Gagné, R. J. & R. W. Duncan. 1990. A new species of Cecidomyiidae (Diptera) damaging shoot tips of yellow cypress, *Chamaecyparis nootkatensis,* and a new genus for two gall midges on Cupressaceae. Proc. Entomol. Soc. Wash., 92: 146–152.

Grossnickle, S. & J. Russell. 1989. Rooting of yellow cypress cuttings. Part 1: Influence of donor plant maturation. FRDA Res. Memo No. 083, For. Can., Victoria, British Columbia.

Hill, C. C. 1923. Parasites of the Hessian fly in the North Central States. U.S. Dept. Agr. Circular No. 923.

Hosie, R. C. 1979. Native trees of Canada (8th ed.). Envir. Can., Can. For. Serv., Ottawa, Ontario.